



# **NTSB Investigation Hearing**

## **787 Li-Ion Battery**

### **Panel 2 — Battery System Design and Development**

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# System Design Objectives

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- Prevent failure but be capable of handling one if it occurs.
- Ensure that no single failure will endanger people or the airplane.
- Redundancy provides multiple layers of protection.



*Continued Safe Flight and Landing Assured*

# Collaborating for Success

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- **Collaboration with Tier 1 partner:**

- Co-located during initial development efforts.
- Requirements and expectations were shared.
- Daily and weekly meetings were held at the working and/or management level.
- Monthly/quarterly meetings were held with senior leaders.

THALES

- **Collaboration with Tier 2 suppliers:**

- Boeing was involved, reviewed selection and concurred.
- Boeing had regular direct involvement, including onsite visits.

GS YUASA

Securaplane

***Extensive Boeing Involvement***

# Battery System Design and Development

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- Boeing and Thales jointly developed Specification Control Drawing (SCD) requirements.
- GS Yuasa, Securaplane and Thales designed and executed developmental tests.
- Design reviews were conducted with Boeing, GS Yuasa and Thales.
- Design reviews, prototype testing, analysis, lab events and Non-Advocate Reviews led to battery improvements.
- Boeing tested battery and charger prototypes to ensure they met airplane system and safety requirements.

***Regular Interaction, Close Contact During Development***

# Design Evolution: Designing for Safety

- **Design evolves with testing.**
  - This iterative process ensures continued improvement.
  - Modifications were fully tested to validate performance.
- **Design evolution was coordinated between all parties.**
  - Boeing updated formal requirements.
  - Boeing, Thales and GS Yuasa conducted developmental testing.
  - Boeing kept the FAA informed of changes and the rationale for them.



***Safety Is the Primary Consideration in Design***

# Summary

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- Boeing was fully involved with its suppliers in battery system design development.
- The battery system design evolved over time as a result of testing and multiple design reviews.
- The certification process verified that the design complied with all Boeing and regulatory requirements.



***Design Evolution Reflects Our Safety Commitment***

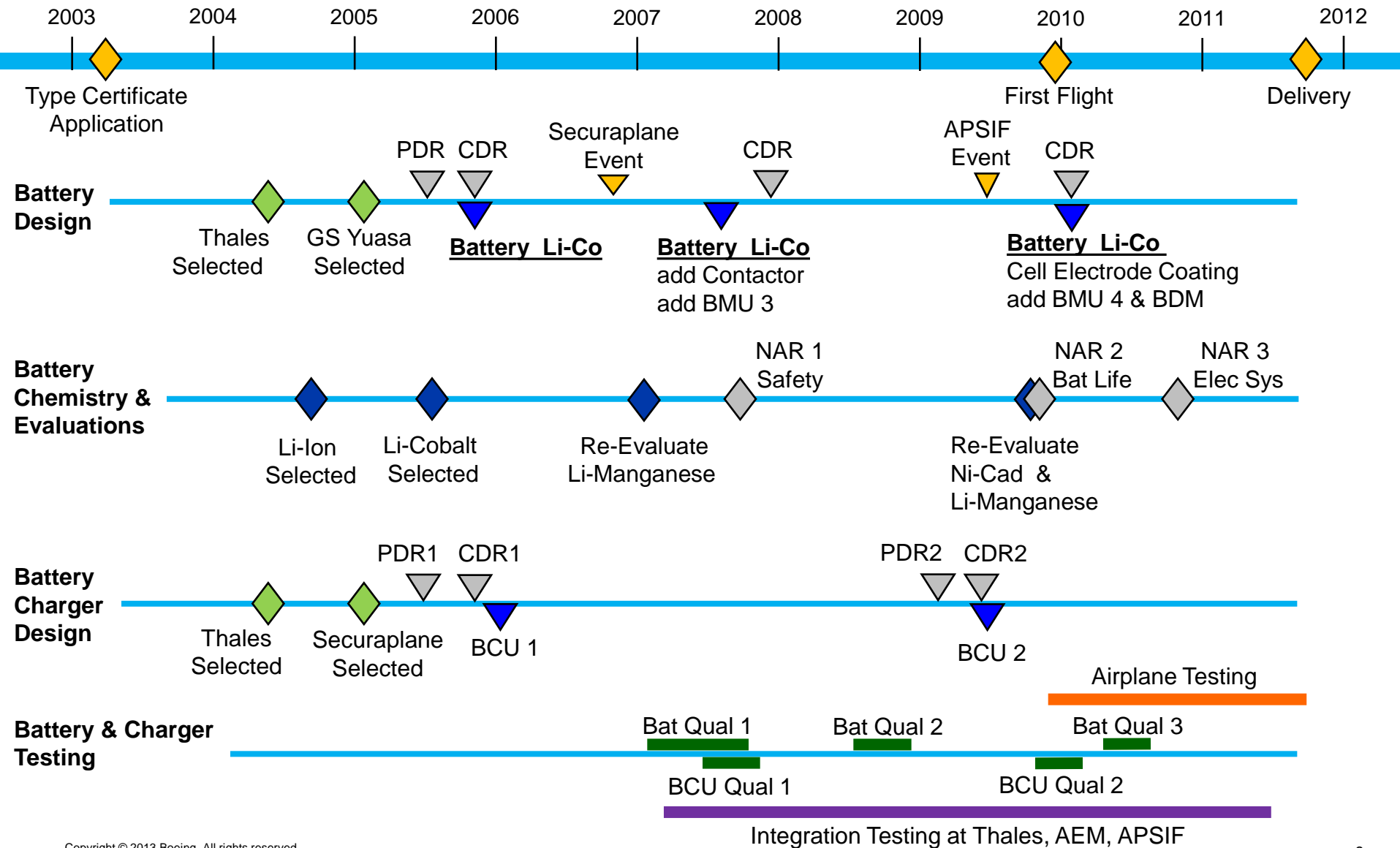


# Backup

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# 787 Battery Design Timeline



# Why Lithium Ion?

- Requirements included:
  - Safety.
  - Power capability.
  - Charging characteristics.
  - Storage capacity.
  - Low weight.
- Technologies evaluated:
  - Nickel cadmium.
  - Lithium cobalt.
  - Lithium manganese.

**787**



**777**



Feature	Lithium Ion (Lithium Cobalt)	Nickel Cadmium
Voltage	32V	24V
Maximum weight	63 lb	107 lb
Current provided for power-up	150 amps	16 amps

***Lithium Ion Best Suited for 787 Requirements***

# Special Condition and Issue Paper

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- **The FAA applied the Special Condition to models built by several manufacturers.**
- **The FAA sent Issue Paper SE-9 to Boeing in June 2005.**
- **Boeing responded to the issue paper in December 2005.**
  - Boeing agreed with the FAA's draft Special Condition and proposed how compliance would be shown.
  - The FAA modified one requirement, regarding flight crew indication of battery capacity, based on Boeing's input.

***FAA Issued the Special Condition in 2007***

# Tests Conducted (1 of 2)

Test Content	Test Article	Test Name	Eng	Cert
Climatic	Cell	High Temperature	✓	
		Low Temperature	✓	
		Altitude	✓	
		Overpressure	✓	
		Temperature Variation	✓	
		Decompression	✓	
	Battery	High Temperature		✓
		Low Temperature		✓
		Altitude		✓
		Overpressure		✓
		Humidity	✓	✓
		Temperature Variation		✓
		Decompression		✓
		Fluid Susceptibility	✓	
Mechanical	Cell	Acceleration	✓	
	Battery	Random Vibration	✓	✓
		Fan Blade Loss / Windmilling Vibration	✓	✓
		High Power Vibration	✓	✓
		Bench Handling Shock	✓	✓
		Shipping Container Shock	✓	✓
		Acceleration		✓
		Electrolyte Leakage		✓

# Tests Conducted (2 of 2)

Test Content	Test Article	Test Name	Eng	Cert
Electromagnetic Interference	Battery	AF Capacitive Coupling		✓
		AF Inductive Coupling		✓
		RF Conducted Emissions		✓
		RF Radiated Emissions		✓
		AF Electric Field Susceptibility		✓
		AF Magnetic Field Susceptibility		✓
		Conducted RF Susceptibility		✓
		Radiated RF Susceptibility		✓
		Induced Spike Susceptibility		✓
		Ground-injected Transient Susceptibility		✓
		Cable-injected Transient Susceptibility		✓
		Lightning Induced Multiple-Burst Transient Susceptibility		✓
		Electrostatic Discharge Susceptibility		✓
		BMU Function Test		✓
Other Tests	Cell	Endurance	✓	
	Battery	Endurance	✓	
		UN Transportation Tests	✓	
		Charge/Discharge Performance	✓	
	Battery and Charger	Battery / BCU Integration Tests	✓	

# Abuse Tests Conducted

Test Content	Test Article	Test Name	Eng	Cert
Abuse Tests	Cell	Nail Penetration	✓	
		External Short Circuit	✓	
		Overheat	✓	
		Crush/Impact	✓	✓
		Step Overcharge Destructive	✓	
		Constant Current Overcharge Destructive	✓	
	Battery	High Rate Charging	✓	
		Nail Penetration	✓	
		Flame Test	✓	
		High Temperature Storage		✓
		Low Impedance External Short Circuit	✓	✓
		High Impedance External Short Circuit		✓
		Overcharge to 36V	✓	✓
		Over discharge		✓
	Battery and Charger	External Short Circuit	✓	